

**SUBJECT:** Miniaturized Multi-Performance  
Test System (MMPTS) for Evaluating  
Human Status in Operational  
Environments - Case 236

DATE: December 29, 1970

FROM: B. A. Gropper

## ABSTRACT

A design concept for a miniaturized multi-performance test system (MMPTS) is presented. It permits in-situ testing of many visual, verbal, auditory and manual performance characteristics under conditions inaccessible to present operational devices. By monitoring performance characteristics in structured situations, changes in functional status may be evaluated more sensitively than by indirect measures based on biomedical status and passive observations of crew activities. Such extension of present laboratory-test capabilities into operational environments would support:

- (a) the detection and analysis of potential problems in their early stages,
- (b) decisions on countermeasures and mission control, and
- (c) the optimization of future man-machine systems.

The MMPTS integrates state-of-the-art test components into a portable unit that is self-contained, small and usable by isolated or mobile operators. By means of multi-channel taped programs, the unit can provide various visual and auditory inputs in both analog and digital form. The user's verbal and manual outputs can be internally recorded, and the combined stimulus-response signals stored or made available for near-real-time readout. If linked by umbilical to a computer, adaptive test programs and real-time analyses can be provided, with some loss in relative mobility. Evaluations can be made of trends within the sets of test-task data (as functions of time or situational changes), of comparisons with performance of operational tasks, and of relations between these test data and concurrent biomedical measures.

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MULTI-PERFORMANCE TEST SYSTEM /MMPTS/ FOR  
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MEMORANDUM FOR FILE

I. INTRODUCTION:

The Need for In-Situ Human Status Information -

In order to design and support effective manned systems we need to be able to measure a variety of human performance characteristics, and predict how they will react under operational conditions (Ref. 1). However, many aspects of human responses are difficult to detect in real-life situations, whether they occur in earth-based activities or in space.

There are two basic problems in studying these response characteristics: (1) their immediate operational effects may be small and only become evident with increased time or stress, and (2) their immediate effects may be transient and masked by later events. In either case, passive observations and before-and-after comparisons are generally too little and too late. We must be able to obtain sensitive in-situ data on human status, and provide near-real-time feedback of results if we hope to understand and potentially control these phenomena. This requires the development of improved measurement techniques that can be used when and where such uncertainties exist.

Unfortunately, present technological constraints often do not permit this data acquisition, and they thereby limit our predictive and control capabilities. For example, many lab studies and simulations have shown that physical and psychological factors - such as sensory overloads and underloads, circadian rhythms, fatigue, hypoxia, contaminants, and zero-gravity psychomotor conditions - can produce effects on human performance, ranging from minor changes to major functional impairment (Ref. 2). Generally, the sensors and diagnostic techniques used are incompatible with in-situ acquisition because of size, mobility or functional constraints.

The net result is that, unless overt changes or failures result, our present monitoring and test capabilities in most real systems are insensitive to most variations in human status.

#### Recent Developments and Implications -

Recent technological advances have succeeded in reducing the size, weight, power and support requirements of potential test instruments and systems. Devices such as portable electromagnetic tape recorders have been made smaller, more sensitive, more reliable, and simpler to operate. Because they can store, display, and record a variety of information with minimal interference with most user activities, these improved devices are finding increasing applications in such areas as remote EKG monitoring, automated instruction, personal communications and recreation.

The potential use of this technology to develop test and data acquisition systems that extend our research and support capabilities is apparent. If we could develop ways to get comparable laboratory and in-situ data we could significantly reduce the risks that sub-critical conditions might escape early detection and be permitted to reach hazardous levels where corrective actions are not possible.

#### Miniaturized Multi-Performance Test System -

The purpose of this memorandum is to document and amplify upon the features of a miniaturized multi-performance test system (MMPTS) whose design concept has been reported to NASA as Disclosure #55, under Contract NASW-417 (Ref. 3). The basic unit of this general purpose system is small, portable, self-contained and capable of many flexible test combinations. In situ status assessment can be made of the human input channels (visual and auditory) and output channels (verbal and manual) that are most used in operational systems. The test system's design permits automated stimulus presentation, response recording, and near-real-time analysis -- both under laboratory conditions and in situations where the human subjects are remote, moving, or otherwise inaccessible to other testing techniques.

The following sections outline: (a) the rationale underlying the definition and diagnostic logic for these operational status tests, and, (b) the basic system's functional characteristics and components.

II. SYSTEM DESIGN AND EVALUATION:Sources of Human Performance Information -

There are three major areas for possible in situ measurement: (1) the men (e.g. biomedical status), (2) their operational environments (e.g. local and remote readouts of systems status) and (3) interfaces between the men and their environments (e.g. from interfacing tools, portable test devices, etc.). If we can obtain adequately sensitive diagnostic data from such man-system interfaces, then we can minimize the methodological constraints involved in direct instrumentation of the men, or in using the operational hardware systems for test and evaluation purposes.

Limitations of Physiological, Environmental and Systems Models -

Analytic models of relations between physiological status and external environments are not yet adequate for describing or predicting most aspects of human performance. They can provide some valuable support information - by assuring that many identifiable failure conditions are absent and, therefore, that survival and nominal performance should be possible. But, since man's operational effectiveness is variable, multi-dimensional, and sensitive to many influences beside physical factors the limited usefulness of these models may be summarized as follows:

- a) It is necessary to assure physiological integrity in order to support nominal performance - but, it is not sufficient.
- b) Passive monitoring may be inadequate, when spontaneous physiological or environmental signals are not available. Provocative testing may be necessary to assess functional status (e.g.: for signal detection and identification, short-term memory, skill retention, etc.).

Analytic reliance on operational systems readouts has similar drawbacks. Well-engineered systems are generally designed to be unaffected by most variations in human responses. Their overall reliability is increased by this insensitivity to differences within and between individuals, but at the cost of limiting their diagnostic capabilities. For example, time-and-motion patterns can be useful for distinguishing between relative efficiencies of different equipment layouts, and

changes in efficiency of human operators. An almost infinite variety of time-motion-force patterns may be used to operate such devices as a simple switch, and knowledge of those patterns can be diagnostically revealing. But a switch is designed to react only to specific types of inputs. Knowledge of its state at any given time can give very little knowledge of the operator's state at that time. Arrays of many such devices permit some gross modeling of time-and-motion patterns, but not as well as devices directly sensitive to such human performance parameters.

In short, assessment of a representative spectrum of human response characteristics requires: (a) multi-dimensional measures and tasks, responsive to variations in those characteristics, and (b) availability of quantitative and qualitative models capable of interpreting the results.

If and when we develop extensive experience and analytic models for complex man-systems-environment combinations, we may be able to reliably predict individual status trends by passively monitoring ongoing activities. Until then, direct tests of human status indicants are necessary. If we can obtain many related types of information within a given situation (See Figure 1), we may enhance our overall confidence and predictive capabilities by balancing the specific advantages and limitations of each source.

#### Rationale of Test Definition and Diagnostic Logic -

The set of tests for the MMPTS was selected so as to satisfy these criteria:

- a. Ability to sample the functional status of the primary human input and output channels (i.e.: Inputs = visual and auditory information; Outputs = verbal and manual response tasks), either singly or simultaneously.
- b. Use of state-of-the-art models and analytic methodology.
- c. Flexibility in programming the specific content and difficulty of individual tests. Capability to provide a wide range of concurrent multi-task combinations.

- d. Capability to serve as a self-contained information source, or as a complementary source to other status indicants (e.g., to supplement information from biomedical, operational task, and qualitative self-evaluations).
- e. Minimal physical constraints or situational interference, in terms of subject-time required for preparation, testing, and resumption of other activities.

The resulting functional test batteries examine human abilities to: (1) receive visual and auditory inputs, (2) process their information reliably, and (3) respond verbally and manually. The logic underlying their diagnostic use involves (a) empirically establishing baseline performance for each of these population/task combinations under controlled conditions, and then (b) comparing these "laboratory" profiles with situational performance profiles. Comparisons may examine performance profiles (e.g. reaction time, accuracy, etc.) as functions of test characteristics or external conditions.

As a research tool, multivariate and correlational techniques may be used to relate test results to task characteristics, to external events within the operational environments, to biomedical data and to real-task performance patterns.

Under operational conditions, significant changes from individual normative profiles may be considered early indicants of potential failure. Such indicants, depending on their severity, would lead to the initiation of (1) contingency procedures, (2) therapeutic measures, or (3) additional specific tests of functional status.

Development of diagnostic information from such tests permits failure modes in primary human task-abilities to be identified relatively directly, rapidly, safely, systematically and with minimum interference with operational systems.

Rationale of Integrated System Design -

Equipment characteristics were defined to be compatible with the preceding logic, as follows:

- a. Control-display package, with analog and discrete codings. Capability to display and record all input-output modes concurrently, or in any desired combinations.
  - Visual displays - capable of presenting discrete on/off signals and continuous spatially-encoded data;
  - Auditory displays - capable of presenting simple tonal signals and complex spoken messages;
  - Verbal outputs - capable of recording the operator's spoken answers - quantitative or qualitative.
  - Manual outputs - requiring discrete psychomotor responses and continuous display tracking.
- b. Maximum use of state-of-the-art technology and hardware components.
- c. Capability for either independent or interactive functioning:
  - Independent mode = totally off-line provisions for program storage, stimulus presentation, and response recording.
  - Interactive mode = real-time program modifications by computer or human test administrator.
- d. Data storage interfaces directly compatible with automatic readout or delayed data-dump techniques (i.e.: all input-output data on magnetic tape).
- e. Capable of unassisted set-up and operation by one man, in either suited or shirt-sleeve modes, and in zero-g or any gravitational orientation.

Basic Functional Components of Test System -

The major functional components are shown in Figure 2 as they would appear to the test subject, and the flow of data within the system is illustrated in Figure 3.

These basic functional components are:

- a. A control handle - capable of responding to lateral pressure (e.g.: "roll" commands), without positional change.
- b. A manual control (pair of push-buttons) - capable of detecting discrete reactions, and relaying signals when one or both are depressed. These may be programmed to result in auditory or visual feedback to the user, as indicated below.
- c. A microphone input - capable of receiving continuous verbal responses from the user via remote communications headset.
- d. An auditory display - capable of relaying speech, tonal signals, or any combination of these, to each of the user's ears independently. Preliminary verbal instructions or other information related to each test, as well as test stimuli may be presented. Each auditory channel may provide competing or complementary signals concurrently.
- e. A set of visual displays for discrete signals (i.e., pairs of lights). - As indicated in Figure 2, these consist of an outer pair of red lights which the test device turns on or off. Immediately next to these is an inner pair of white lights which the user controls (via the discrete-response buttons) and which provide him with real-time visual feedback. Internal reference signals can be used to control these lights, so the inner pair responds only when the outer discrete displays are programmed. When the displays are inactive the buttons only transmit reaction data to the recording device.

- f. A central visual display for continuous signal tasks (i.e., aligning indicators in a pursuit-tracking mode). - As indicated in Figure 2, this display is bilaterally symmetrical, with an unnumbered calibrated background. Since it has no alphanumeric symbols, it can be viewed horizontally - with the main handle at either side - or even vertically, with the handle toward the user.

This analog display presents two movable elements. The stimulus target (e.g., a hairline with a central open circle) is programmed by the test device, and may follow any forcing function (e.g.,) sinusoidal, randomly perturbed, etc., depending on the operator characteristics being evaluated (See Refs. 4, 6, 9, 11). The second movable element (e.g., a hairline follower) provides continuous response feedback of the user's control inputs.

- g. Internally, the device's main body consists of two modular sub-units: (1) the program housing, providing tape transport, stimulus-playback, and response-recording capabilities, and (2) the control-display housing, with associated signal-processing electronics.

As shown in Figure 2, independent operation is the primary mode, (i.e., with a self-contained tape unit). However, the program sub-unit may be removed, and the control-display unit may either be tethered to a computer by an umbilical, or secured to a task panel for fixed-location testing.

The flow of test data for independent and interactive programming is shown in Figure 3. In the interactive mode an on-line computer is used to adapt the stimulus programs to the subject's real-time performance, without intermediate input-output data storage on the internal tape unit (Ref. 11). For interactive testing the general form of adaptive logic is:

$$S_z = \sum_{i=1}^Y f_i(S, R)$$

in which the characteristics of the Zth stimulus, or task segment, are based upon a cumulative analysis of the subject's patterns on the preceding y segments, using pre-programmed performance criteria.

Feasibility with State-of-the-Art Technology -

Pre-prototype estimates indicate that all these features can be satisfied with state-of-the art hardware and software technologies. The need for analog signals (e.g.: audio & voice) constrains the data system more than the digital input-output data. Since the same tape medium is used concurrently for stimulus presentation and response recording, its minimum operating characteristics must be adequate for both voice and data needs. Therefore, state-of-the-art portable audio tape-recorders (using miniaturized solid-state or integrated circuit packages) can serve as tentative checks on the feasibility of integrating these hardware capabilities.

- a. Continuous recording of analog and digital signals, satisfying requirements of voice intelligibility (@ 3 KHZ Band width) is readily available. Essentially the entire audible spectrum (@ 20 HZ - 20 KHZ) can be covered, with negligible speed fluctuations or signal variations.
- b. Simultaneous multi-channel record and playback capabilities (e.g., "stereophonic", "quadriphonic", etc.) are available. Laboratory quality systems covering 20 channels are in commercial use.
- c. Record - playback heads are available in 8-track formats for the standard 1/4 inch audio tape width.
- d. Simple replaceable tape packages have been developed in several formats (e.g.: "cartridges", "cassettes", etc.). These can provide from 15-45 minutes of continuous operation, and are functionally equivalent -- except for search and rewind capabilities.

- e. Compact and reliable power sources and electro-mechanical components (tape transports, signal processing electronics, controls and displays, etc.) are widely available. Integrated circuits can provide all electronic functions within the basic volume determined by control-display needs.

For example, standard 8-track cartridges now have two access ports, each of which can accommodate a record or playback head for 4 of the 8-tracks. One head (A) can play the 4 pre-recorded stimulus tracks while the other (B) concurrently records synchronization and response data.

The allocation of functions in this 8-track format is indicated in the following table:

<u>Channel</u>	<u>Function</u>	<u>Head</u>	<u>Variable</u>
1	Synchronization	B	On/off and Time-marks
2	Stimulus	A	Audio (Left channel)
3	Response	B	Voice
4	Stimulus	A	Audio (Right channel)
5	Response	B	Manual (Continuous)
6	Stimulus	A	Visual (Continuous)
7	Response	B	Manual (Discrete)
8	Stimulus	A	Visual (Discrete)

State-of-the-art diagnostic and modeling techniques are equally applicable to the laboratory and operational use of these tests (Refs. 4, 7, 8). The system's self-contained test capabilities can provide time and accuracy measures appropriate to many status evaluations: for example, operator response speed and flexibility (Ref. 6), performance with different types of concurrent cross-modality information (Ref. 5) and reactions to changes in situational priorities by which selected tasks become "primary" or "secondary" (Refs. 9 and 12), in addition to task-loading stresses. As indicated in Figures 4 and 5, operator response speed can be analyzed to

reveal component times under different task conditions. Central information processes may range from the simplest reflexive reaction decisions to complex choices among possible multiple responses; and these central processes make up the largest and most variable part of total response time (Ref. 6).

Adaptive computer programs, which continuously evaluate performance profiles (Ref. 11) are relatively well developed for manual-control systems, but do not presently lend themselves to evaluation of most verbal and symbolic materials. Since an on-line computer involves either umbilical tethering or telemetry, these represent a loss of some relative user mobility. They do, however, permit real-time readout and analysis.

#### Evaluation of System Features -

The fundamental advantages of this proposed system are: (1) portability, and (2) reproducible inputs and outputs. These provide the potential to fill-in many present informational gaps, through modular tests of basic human input-output functional capabilities where such data are presently limited or unavailable.

The advantages of portability, at the cost of comprehensiveness, are evident in many areas that are now taken for granted. For example, first-aid kits, portable tools, cameras, radio and video receivers, biomedical telemetry, and tape recorders all offer advantages over their non-portable counterparts which more than justify their lack of some of the larger devices' capabilities. The present system attempts to provide at least a reasonable first-level status assessment of the most important operational aspects of man's primary informational channels (Refs. 4, 5, 7, 8). It is intended to complement larger test facilities (e.g.: IMBLMS) where they are available, and provide safety assurance and primary monitoring data where they are not. It permits the use of the same tests under laboratory and operational conditions, under IVA or EVA, under zero-g, and with the operator free-floating or supported.

Some inherent limitations exist in all testing systems, since totally non-interfering tests are an essentially unattainable ideal. Whether provocative tests involve taking the man out-of-the-loop psychologically by momentary distraction or by physical removal to a test facility, the effects of such situational and motivational factors must be considered. The present portable test system attempts to minimize these effects and to extend objective laboratory-data capabilities into operational environments. However, with motivation equal

to that obtained in laboratory settings, it can also provide the same type of verbal and task-data as self-reports, debriefings, task-simulations, and other status assessment methods. Insofar as sensitive and valid measurements can be devised, the present system's relative freedom from equipment constraints can be advantageous.

Important advantages result from the ease and flexibility of programming, and the ability to function in many environments. A single man can test himself without assistance and the device can be totally reprogrammed simply and rapidly, by changing tape cartridges. In addition, the unit can acquire data within a wide variety of non-space applications, including (a) those where a temporary test capability is desired, and (b) those where no interface changes are possible. For example, it can be useful in many stressful situations involving remote operations in cramped quarters (e.g.: military and industrial surface-vehicles, multi-man aircraft, mining and undersea habitats). The ability to objectively test one- and two-handed tasks without requiring external support can be a useful feature, insofar as it minimizes interface requirements. Equivalent tracking performance has been found when similar manual controls are hand-held or supported by the operator as when they are externally supported (Ref. 10). In addition, the side-effects of functional loss of visual information may be safely investigated with auditory tasks, while the operator's visual field is temporarily obscured. The system is also essentially fail-safe, since independent operation does not involve reconfiguration or reorientation of the larger manned system, and failure of the test unit would not affect the operational system.

Finally, the miniaturized test system offers flexible potential both as a system research tool and for operational support. Multi-task monitoring and vigilance effects can be investigated, with any of the component tests designated as the primary (i.e. high-priority) activity. Any of the other tests can be combined as a secondary load (either within the same sensory modality, or across modalities). With appropriate cost-reward structures, the operator's abilities to allocate his effort and accuracy may be tested safely under time-sharing stress conditions (Ref. 5, 9 and 12). The basic device may also be interconnected, so that two or more can be used to study small group real-time interactions, game situations and other applications in which the subject interacts with a real, or simulated, other person. This permits the modeling of multi-man cooperative and communications factors, via psychomotor or verbal responses.

III. SUMMARY:

Valuable research and operational support data could be obtained if present laboratory-test capabilities are extended into operational environments. This is especially true in situations where intermittent monitoring of biomedical measures and passive observations of crew activities cannot provide sufficiently sensitive information on each individual's functional status.

Miniaturized multi-performance test capabilities appear feasible with state-of-the-art technology. Self-contained, small, and portable test systems, using multi-channel taped programs, can provide a range of visual and auditory inputs to assess a human operator's functional status. Analog and digital data can be internally recorded, and the user's verbal and manual response signals stored or analyzed in real-time. Adaptive test programs utilizing an on-line computer can be provided if some loss in relative mobility is acceptable.

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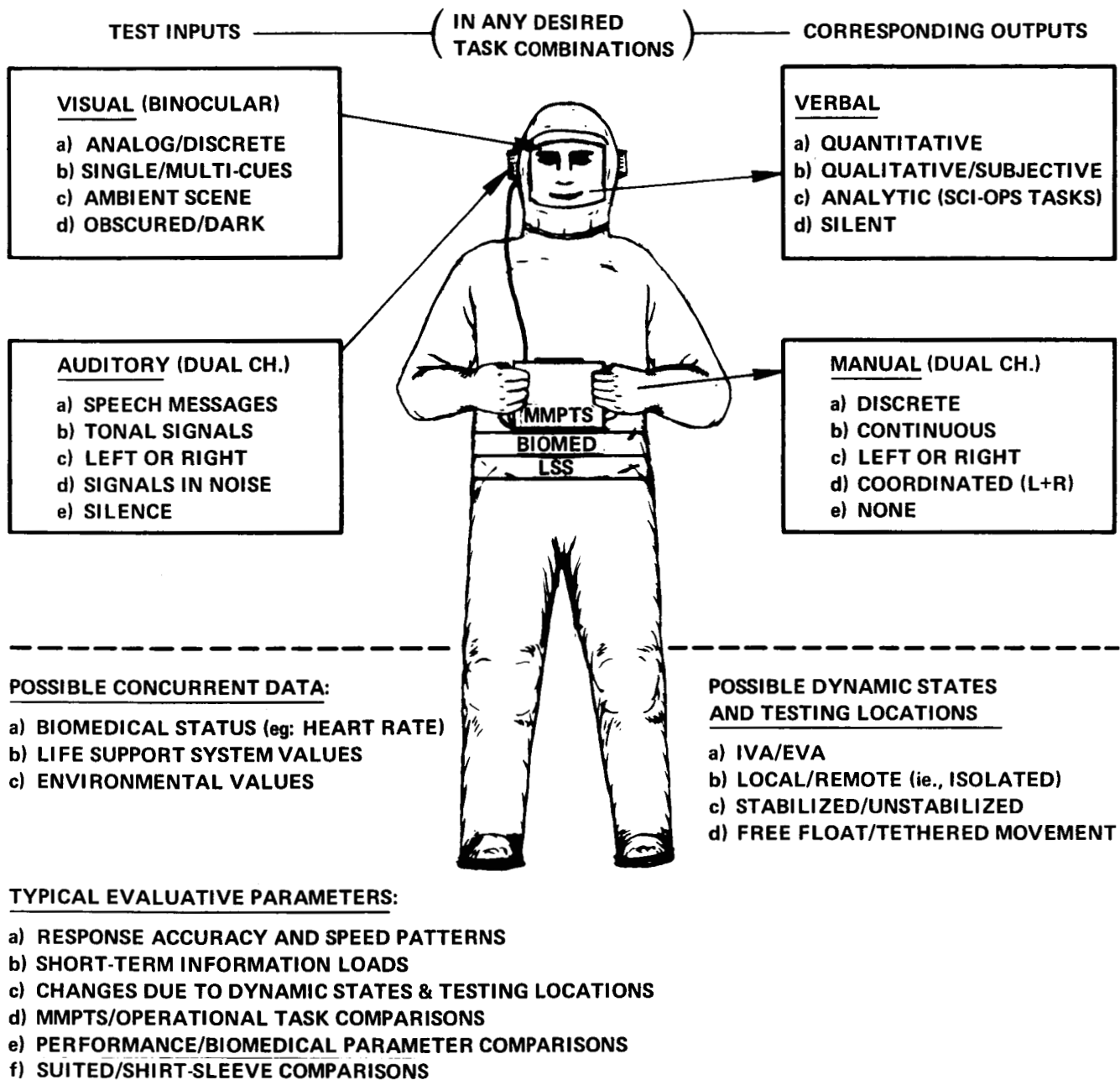
Attachments

  
B. A. Gropper

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**FIGURE 1 - MINIATURIZED MULTI-PERFORMANCE TEST SYSTEM – (MMPTS)  
SUMMARY OF TEST CAPABILITIES**

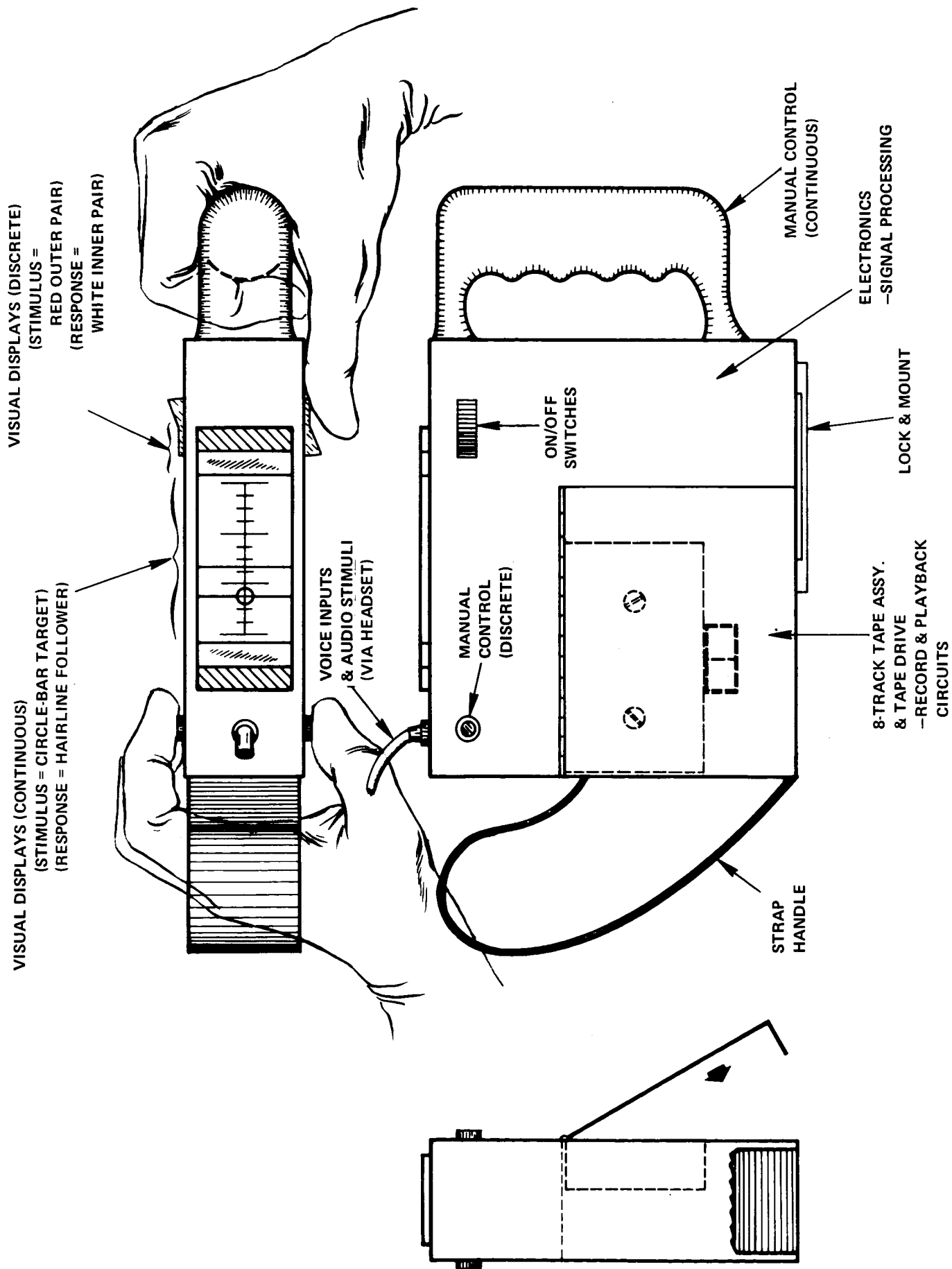


FIGURE 2 - BASIC COMPONENTS AND CONFIGURATION OF MINIATURIZED MULTI-PERFORMANCE TEST SYSTEM (MMPTS)

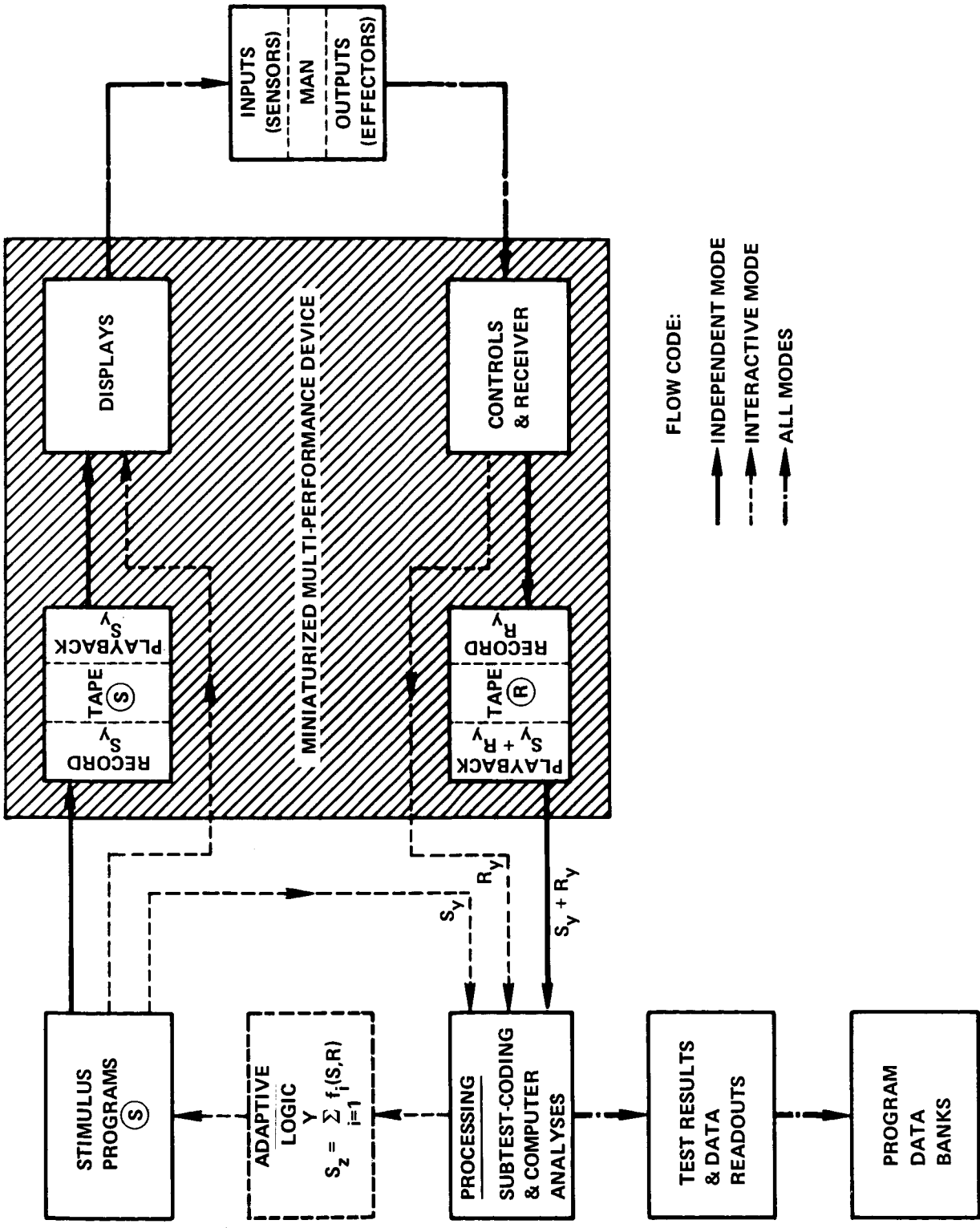


FIGURE 3 - FLOW OF TEST SYSTEM DATA

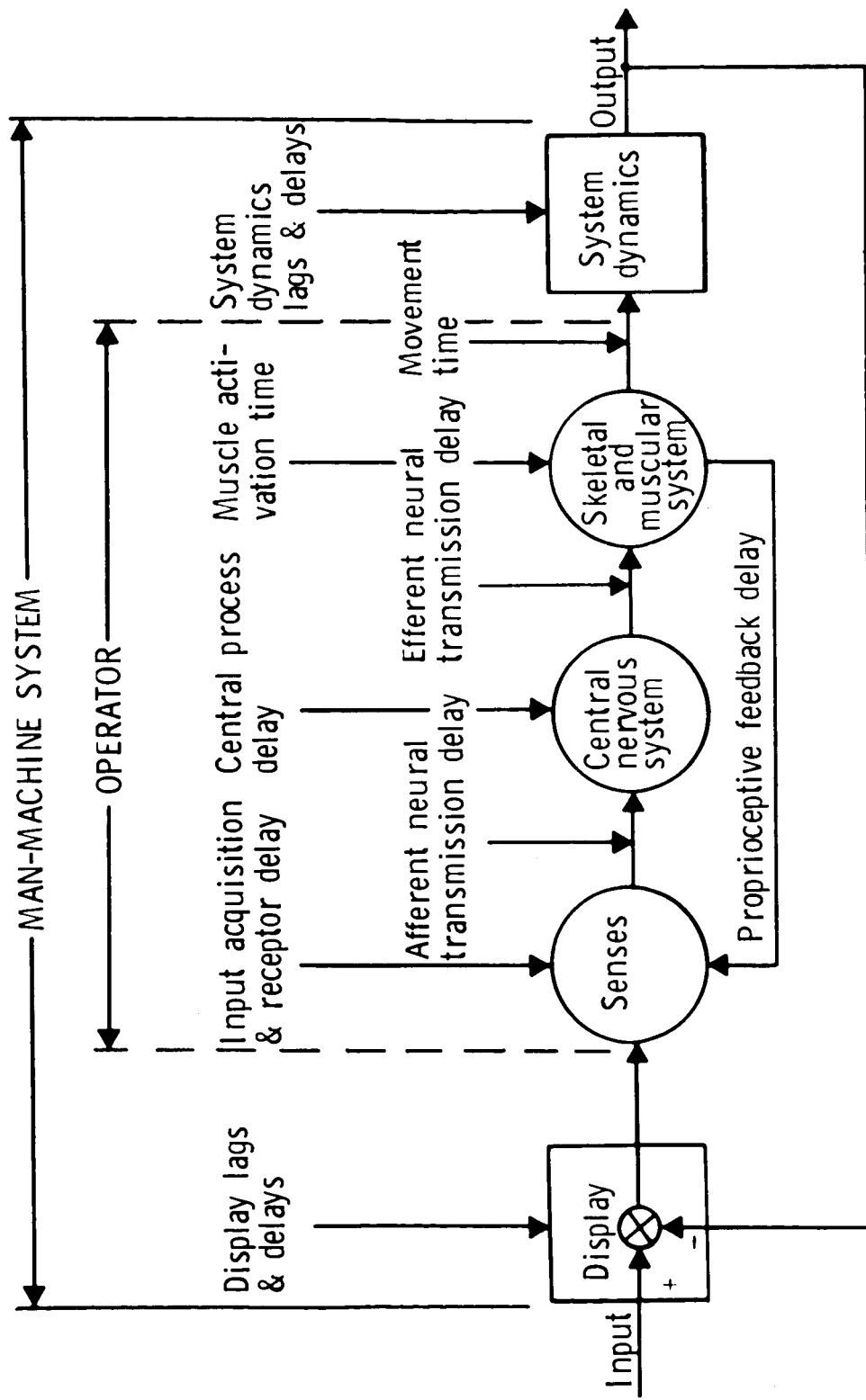


FIGURE 4 - SCHEMATIC DIAGRAM OF OPERATOR AND SYSTEM LAGS AND DELAYS IN A MANUAL CONTROL SYSTEM

<u>Delay Basis</u>	<u>Delay in ms</u>	
	<u>One-Choice</u>	<u>Disjunctive Task</u>
Receptor delays	1-38	1-38
Afferent transmission delays	2-100	2-100
Central process delays	70-100	90-300
Efferent transmission delays	10-20	10-20
Muscle latency and activation time	<u>30-70</u>	<u>30-70</u>
Reaction Time or Total Delay	≈ 113-328	133-528

Figure 5. Estimates of Manual Reaction Time Components, for Visual or Auditory Tasks Involving Simple and Multiple Stimulus-Response Combinations.

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